THE CIRCULAR FUTURE OF PLASTICS
FUNDAMENTALS AND INNOVATION CHALLENGES

International Recycling Forum

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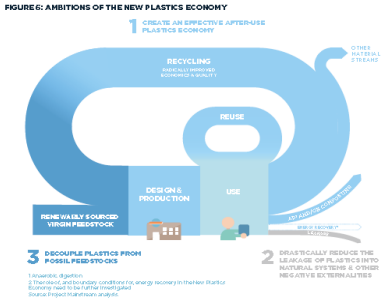
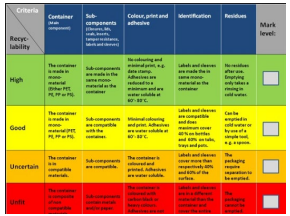
PLASTICS RECYCLING = HOT :
HOWEVER, DIFFERENT PERSPECTIVES…

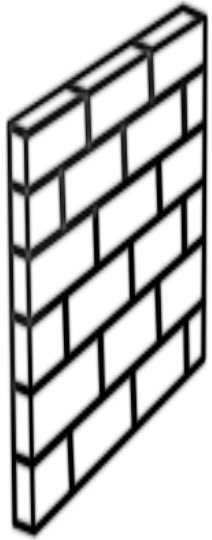
eco design

Design for Recycling

Recycle MAKE A DIFFERENCE!







Recycler's CEO :

"Our profession is ***cursed …***"

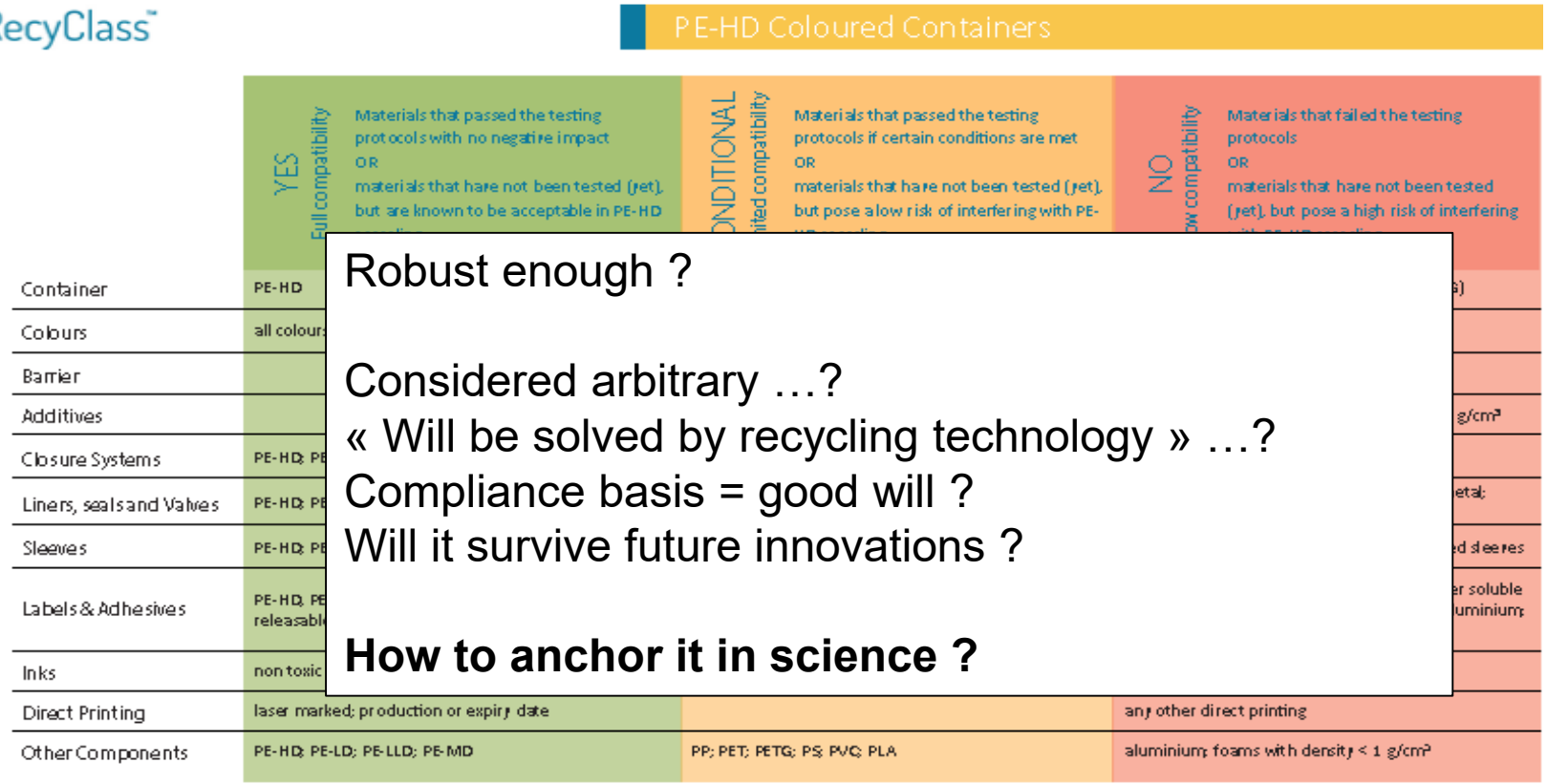
« The messages are OK, but reality goes <u>systematically</u> in the wrong direction »

« Every <u>innovation</u> creates new problems »

TOTAL

DESIGN FOR RECYCLING : PRAGMATIC APPOACH

RecyClass



Robust enough ?

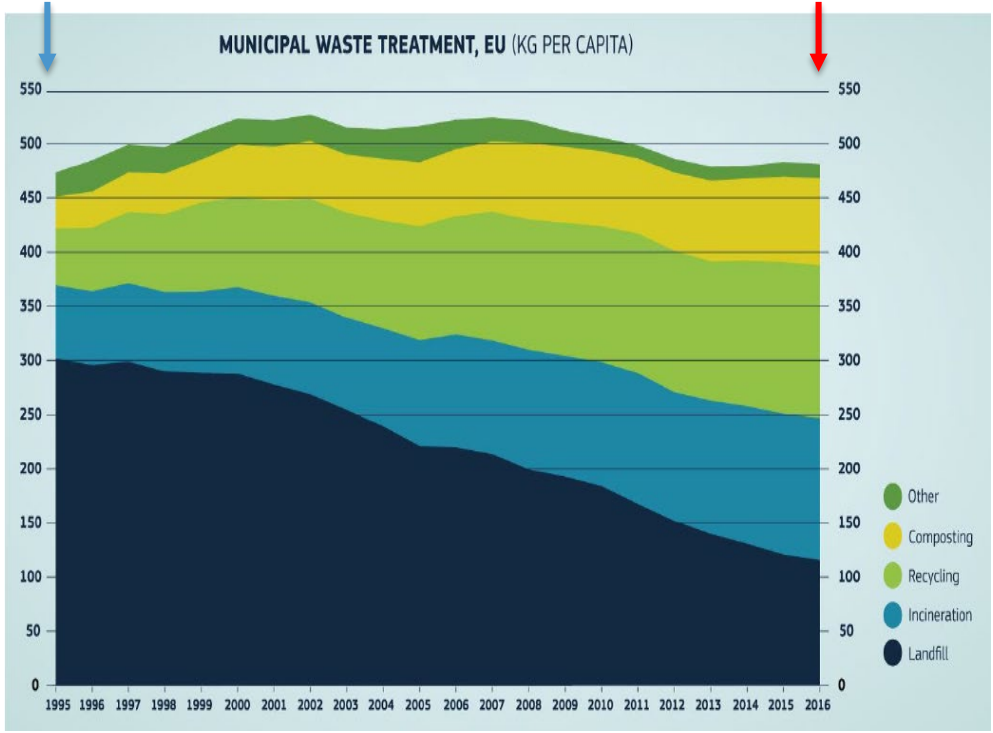
Considered arbitrary …?
« Will be solved by recycling technology » …?
Compliance basis = good will ?
Will it survive future innovations ?

How to anchor it in science ?

PARADOX: MEASUREMENT VS. PERCEPTION OF WASTE

1 ton plastic = 15.000 packages

1 ton plastic = 40.000 packages



Source : EU Plastics Strategy document, 2017

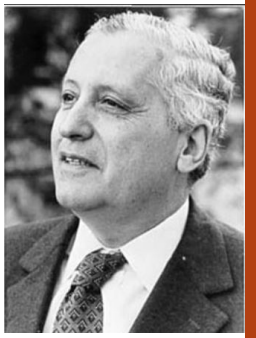
'Waste' expressed in Tons : logic…?

3 advantages of 'mass':

1) Easy to measure
2) It is not lost, can be followed through the chain
3) Estimation of potential economic value after recycling

Disadvantage : *mass is quite irrelevant to express the 'waste quality' …*

WASTE IN FUNDAMENTAL PHYSICS



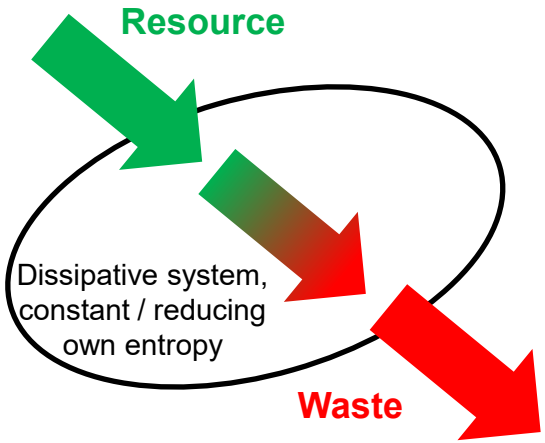
Ilya Prigogine : « the father of Entropy »

Nobel prize 1977 : Thermodynamics of « dissipative systems »

- Dissipative system can keep its entropy constant or reduce it :

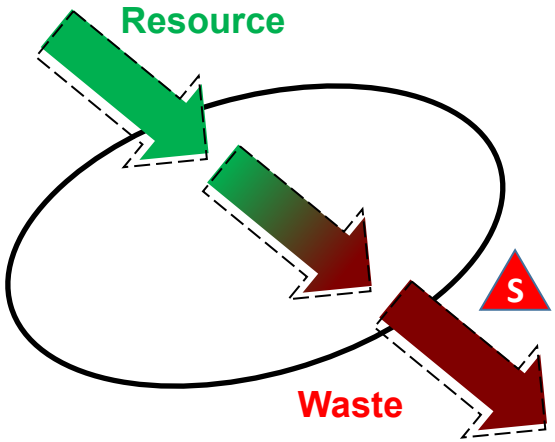
  by importing low entropy (resource) and exporting high entropy (waste)

  - Planets, humans, the biosphere, the antroposphere, …
- Waste = **high entropy** output (material, energy : dispersed, mixed, spread, heat energy)
- Resource = **low entropy** input (material, energy : concentrated, pure, ordened, non-heat energy)



LINEAR VS. CIRCULAR OPTIMISATION

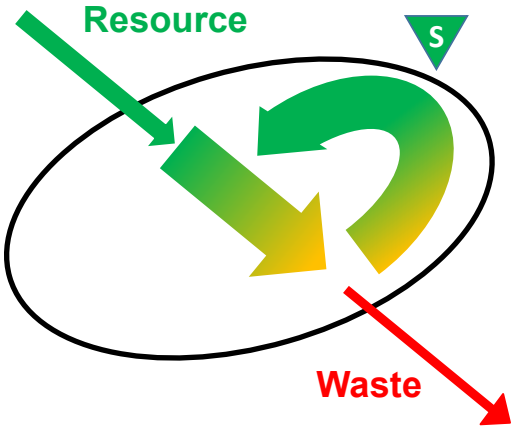
« Resource reduction… »



Less tons BUT higher entropy = ***more waste***

Observation bio-systems :
internal circularity minimises waste generation
– ***based on low entropy processes !!***

Re-use / recycle …



Significant *waste* ***reduction***

CIRCULAR PROCESSES ARE BY DEFINITION *LOW ENTROPY* PROCESSES !

- Brake of a regular car : kinetic energy transformed into heat, then dissipated : 2 x strong entropy increase…

« LINEAR BRAKE »

- Brake of a hybrid car : kinetic energy transformed into electrical energy, then into chemical energy (battery), readily available for re-use : almost no entropy increase…

« CIRCULAR BRAKE »

CIRCULARITY OF A PROCESS = SAME AS *REVERSIBILITY*

Initial process

Optimized for max.
'A to B' efficiency (economics)

Pure
Concentrated
Ordered

Material / energy
Status A
Low entropy

Material / energy
Status B
High entropy

Contaminated
Dispersed, spread
Mixed

'B to A' efficiency (economics) depends *structurally* on limited entropy increase of **initial** process !

Reverse process

TOTAL

PLASTICS ENTROPY EVOLUTION DURING LIFE CYCLE









Initial process

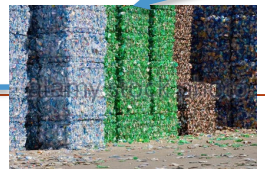
Zone of 'no return'

Reverse process



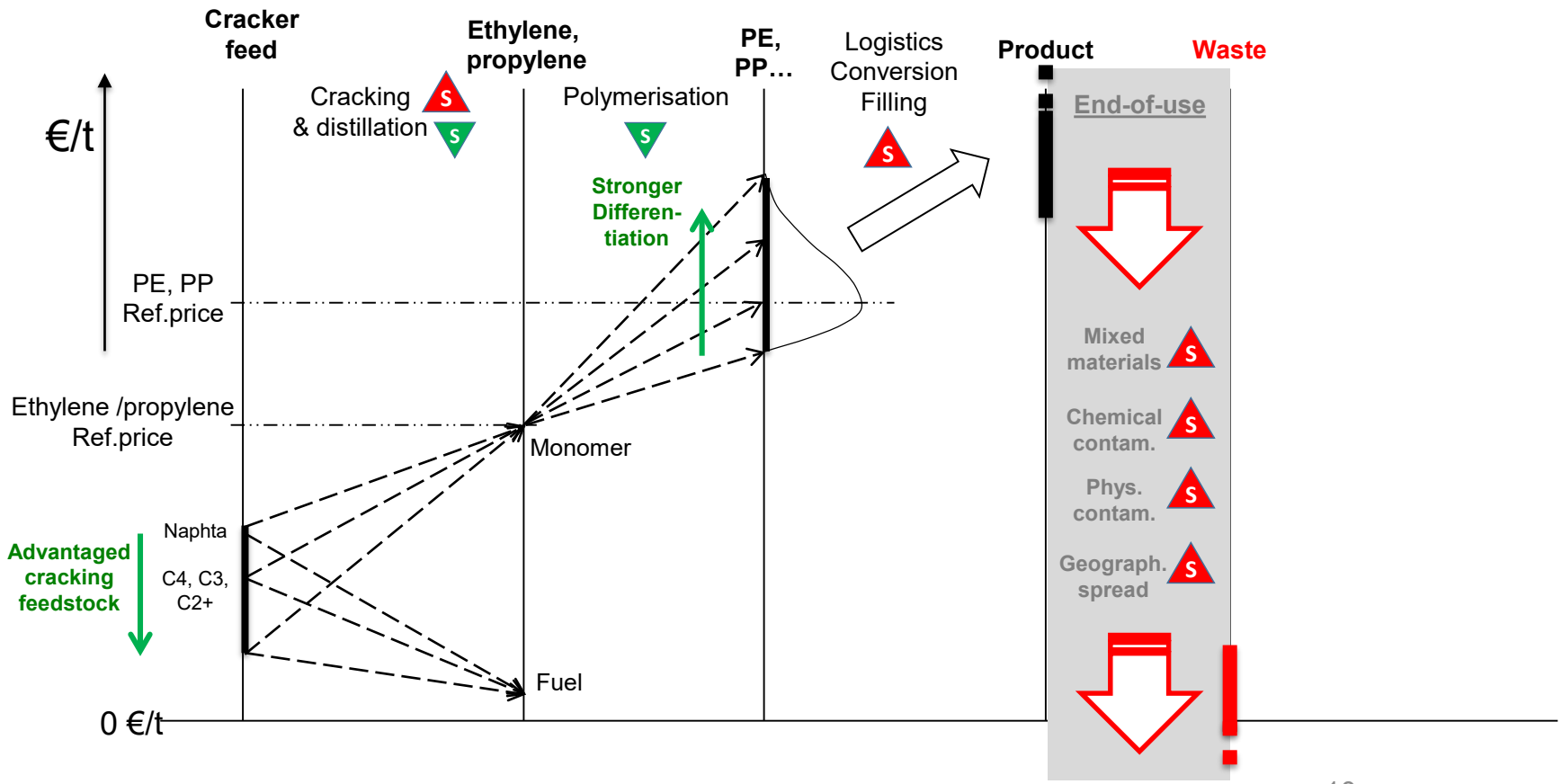




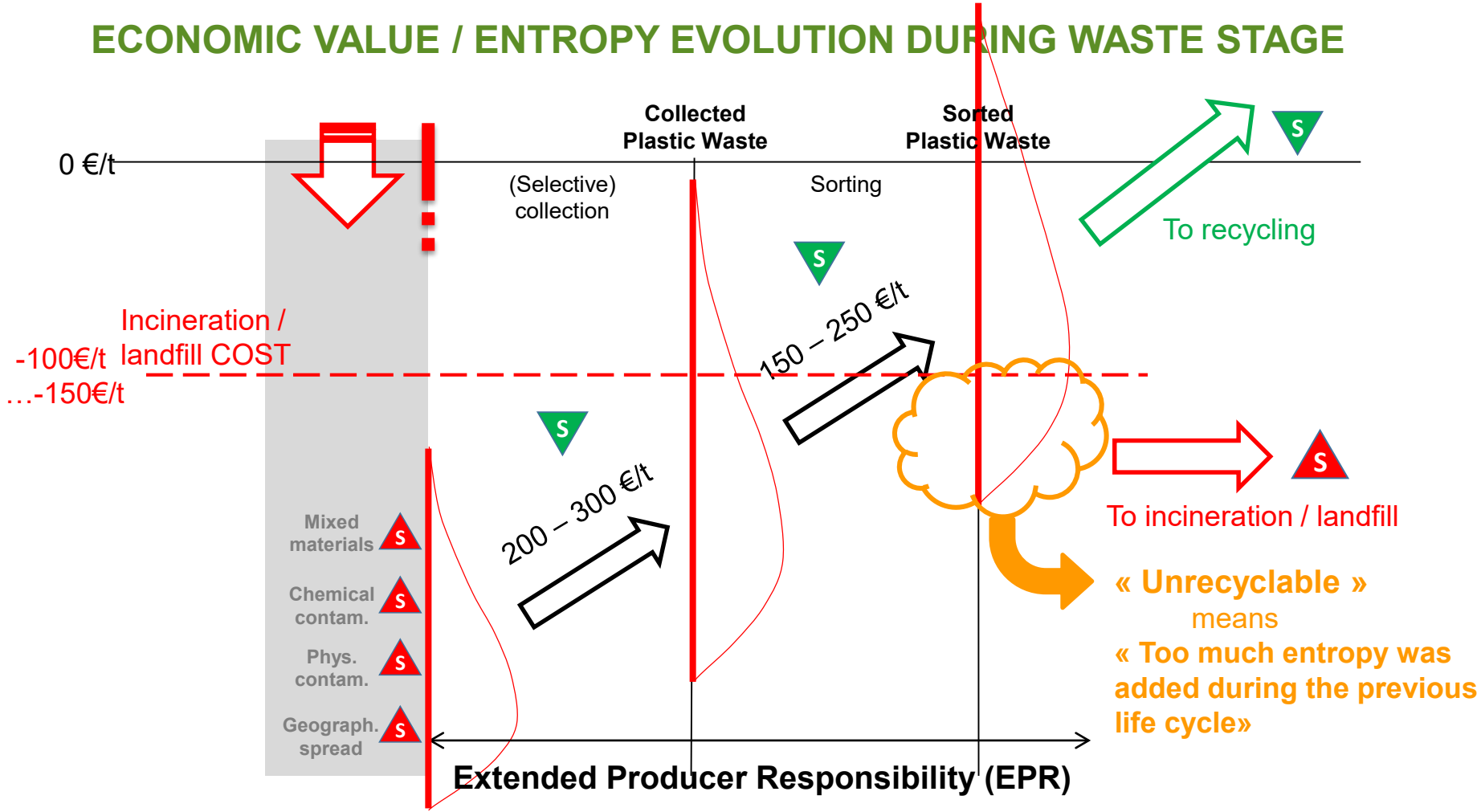




TOTAL

ECONOMIC VALUE & ENTROPY EVOLUTION OF POLYMER MOLECULES



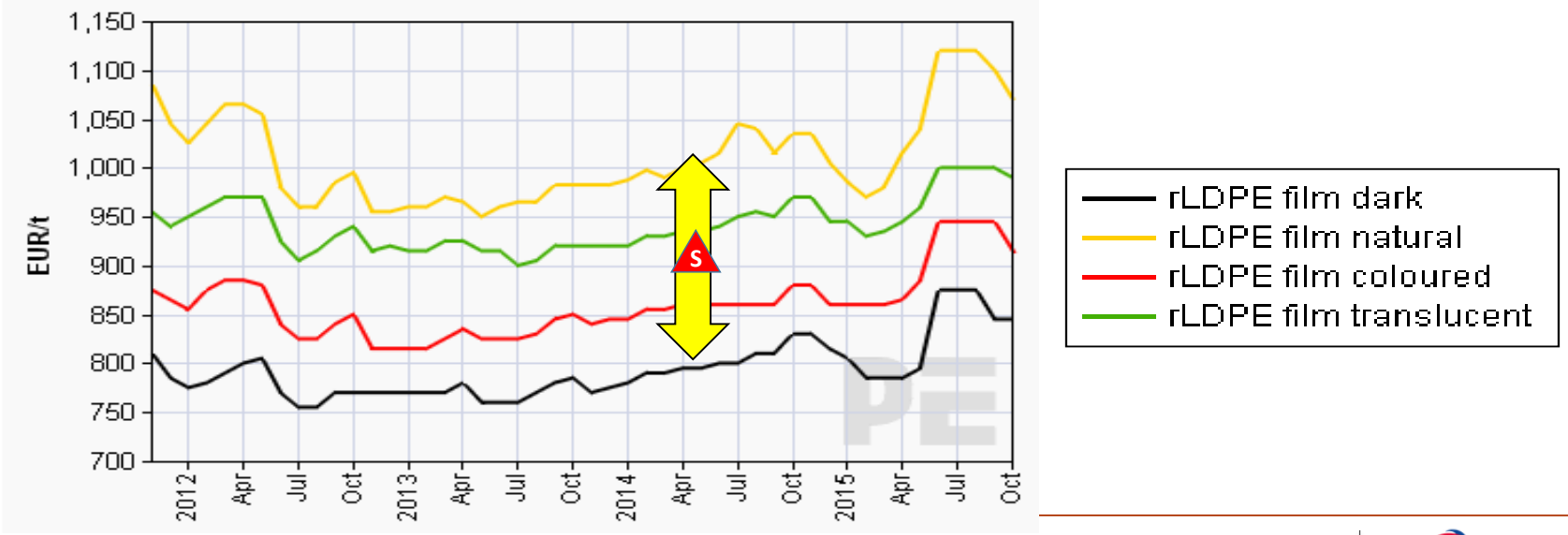
ECONOMIC VALUE / ENTROPY EVOLUTION DURING WASTE STAGE



PLASTICS :
HEAVY ENTROPY INCREASE BY IN-MASS COLORATION !

Considered ‘recyclable’ but everybody assumes that the pigment can stay in….
The recycling process itself can add even extra entropy by mixing all colors …

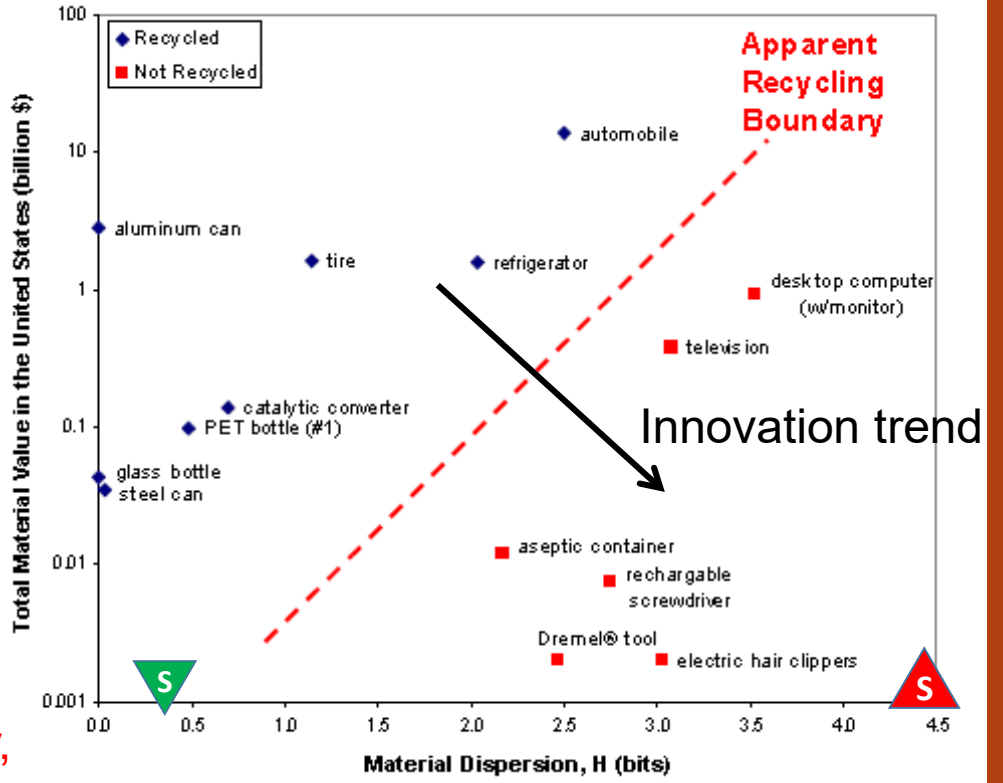
Consequence of high entropy = destruction of ‘circular economics’ !
Natural recyclate has 200 €/t more value than coloured recyclate : better access to virgin markets !



ENTROPY, RECYCLABILITY AND PRODUCT DESIGN / INNOVATION

- M.I.T. Paper ‘Mixing Entropy and Material recycling’

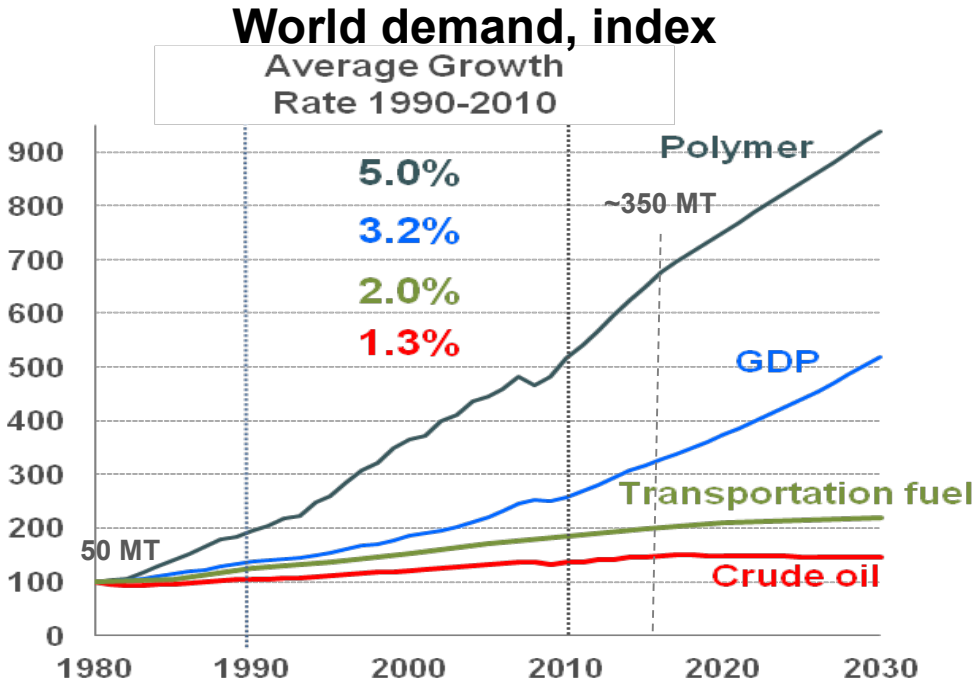
- « Society recycles those materials with high ‘total material value’ and low dispersion (entropy) »
- « Designers are constantly moving products to the lower right corner : using less expensive material and increasing functionality, often by more components and materials »



If innovation / design is not *focused* on circularity, it will tend to increase entropy, ‘together with nature’ (= easiest) and become an **engine of linearity**…

Source ‘Mixing Entropy and Material Recycling’, Timothy G. Gutowski and Jeffrey B. Dahmus (MIT)

PLASTICS HISTORICAL SUCCESS STORY :
RELENTLESS INNOVATION - GENERATING LINEAR GROWTH



Plastics = material with highest **innovative capability** – *pulling it spontaneously towards higher entropy : linearity…*

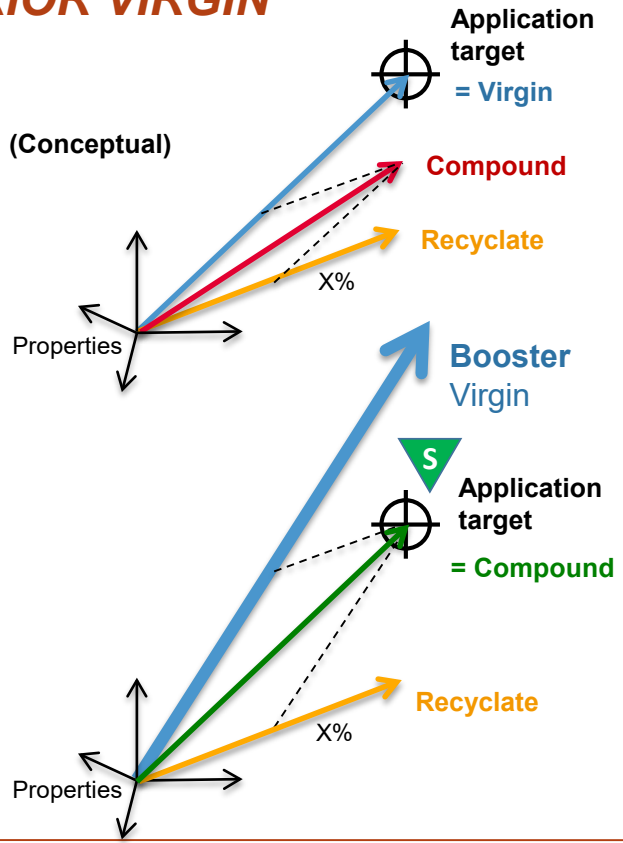
Can we, *together,* focus plastics innovation on *circularity* ?
(low entropy innovation)

TOTAL CIRCULAR COMPOUND CONCEPT :

BOOST RECYCLATE WITH SUPERIOR VIRGIN

- Usual :
  - Virgin design = **optimized** for application
  - Virgin + recyclate = structurally inferior ; tendancy towards less demanding applications

- Cicular Compound :
  - Virgin design = **for boosting** recyclate into applications for optimized use
  - Virgin + recyclate = optimized for application



LATEST DEVELOPMENT : CIRCULAR SHRINKHOOD

TOTAL

oerlemans plastics BV

morssinkhof-rymoplast
The Art of Plastic Recycling

Booster PE

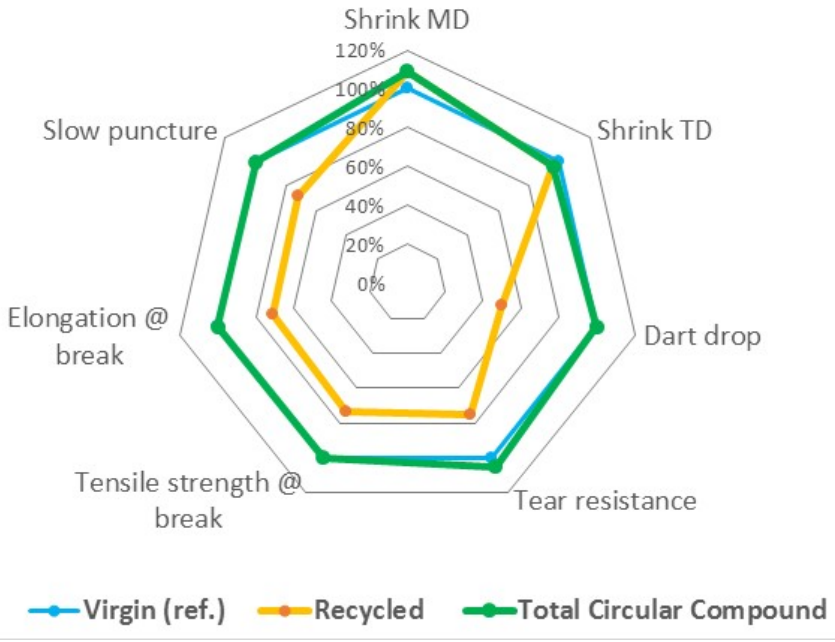
50%

Wienerberger

valipac
FOR A SUSTAINABLE FUTURE

go4 circle

Circular shrink hood, 50% recycled content :
technical equivalency with virgin



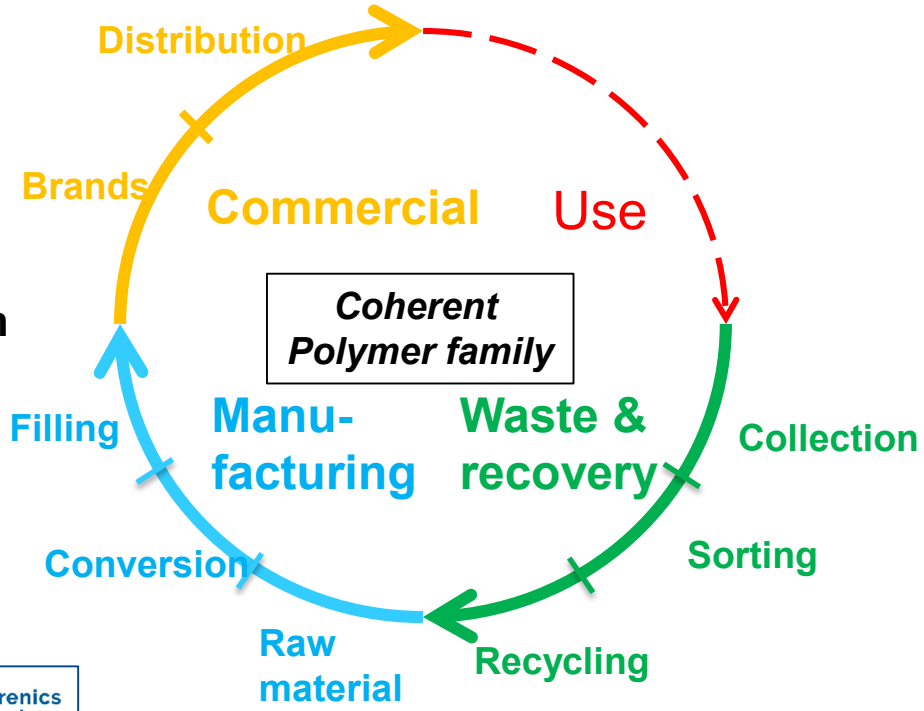
TOTAL

INDUSTRY CONFIGURATION FOR PLASTICS CIRCULARITY: CIRCULAR VALUE CHAIN PLATFORM

- **Cooperation of all actors of the circular value chain : making circularity ROBUST**

- **High effectiveness in terms of**
  - **credible commitments vs. society with circular economy ambition**
  - ***material excellence***

Reducing industry's organisational entropy …



petcore Europe | vinyl plus COMMITTED TO SUSTAINABLE DEVELOPMENT | PCEP POLYOLEFIN Circular Economy Platform | Styrenics Circular Solutions

HOW CAN A POLYMER BE SUCCESSFUL IN THE CIRCULAR ECONOMY

Required characteristics ?	*Current champion*
Very insensitive to multiple processing : - Mechanical recycling into multiple life cycles…	 **PS**
Easy to apply dissolution processes : - Effective extraction of additives, colorants, contaminants…	 **PS**
Easy depolymerising into high value monomer - Access to full range of applications	 **PS**

>1 million T/y of polystyrene packaging waste available !

Mostly from food contact application …

TOTAL

Plastic waste partners

CORE PLA

TOMRA SORTING SOLUTIONS

valorplast

cicloplast

plarebel

CONVERSIO Market & Strategy

Technologies

Chemical / dissolution / mechanical

Value chain

Styrenics industry

TRINSEO

TOTAL

REPSOL

eni

INEOS STYROLUTION

versalis

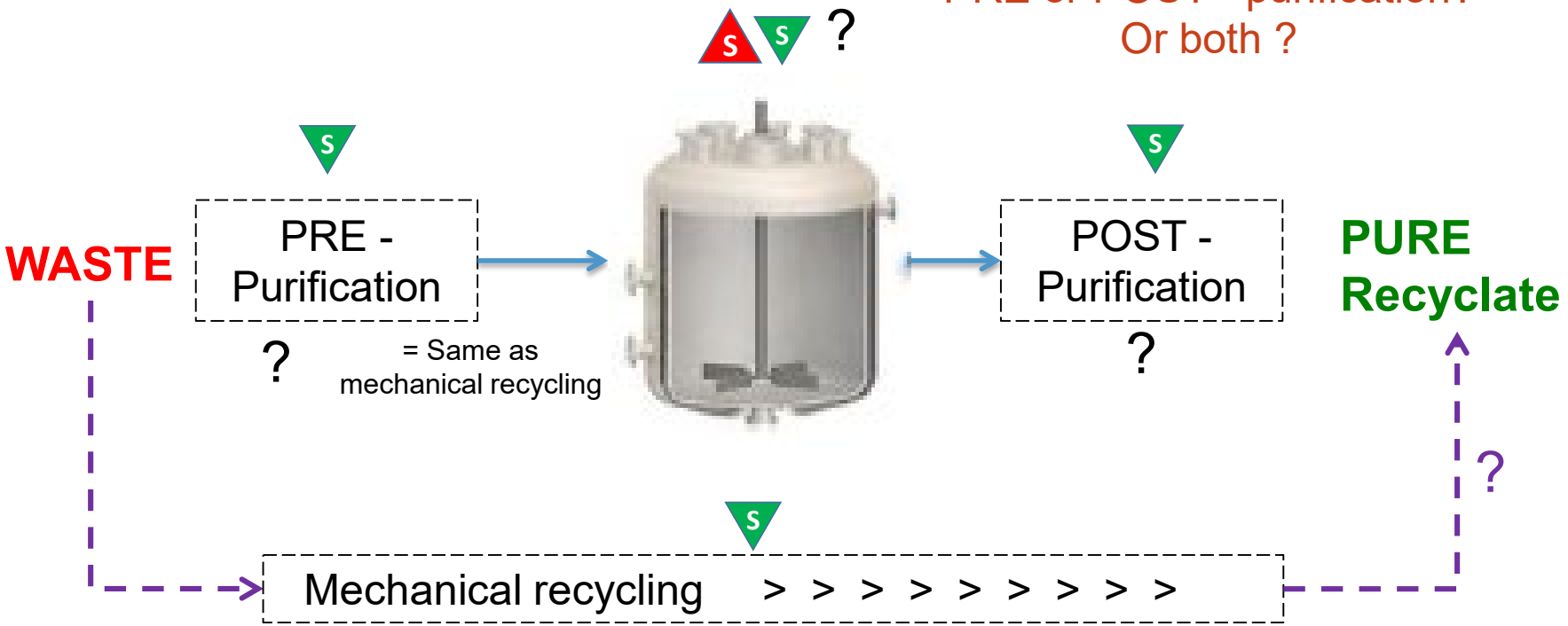
Styrenics Circular Solutions

The road to polystyrene circularity

www.styrenics-circular-solutions.com

CHEMICAL / DISSOLUTION RECYCLING : GENERIC QUESTION

PRE or POST - purification?
Or both ?



MECHANICAL HIGH PURITY PS RECYCLING

Reference = PET recycling :

Target = bottle-to-bottle, food contact and transparency : 99,95% purity – food contact

Technology stretch : necessary quality maximisation in all operational aspects (investment, operational management)

Process :
- DEEP PRE-SORTING
- HOT CAUSTIC WASH
- FLAKE SORTING – mat.+ color
- SUPER CLEANING
- (melt filtration = accessory)

SCS testing on packaging PS :

Demo by TOMRA : excellent sortability of PS !
HIPS (even by rubber content) – GPPS – EPS/XPS

Selection of the best hot wash process in the market
(very strong differences in measured performance)

Existing TOMRA technology

Result : high purity HIPS flakes 99,9%
(+ similar result for EPS/XPS washing)

+ mechanical food contact project launched SCS/Fraunhofer

2020 : Design for Recycling - - - the 100% PS yoghurt pot …

TOTAL

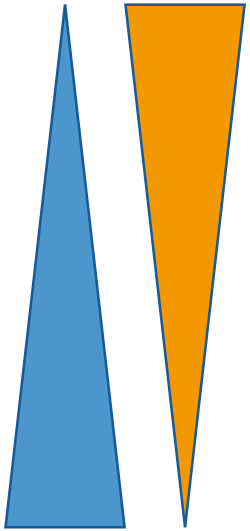
HOW TO USE ENTROPY IN POLICY TOWARDS CIRCULARITY ?

HIGHEST HIERARCHY OF RULES : TO PROVIDE LT STABILITY

Completeness, Coverage

Civil society rules

1. Human rights
2. Constitution
3. Laws
4. Ministerial memos



Circularity drivers

1. ***Aim for lowest entropy***
2. Ladder of Lansink
3. Circular design / Recyclass…
4. EPR fee modulation

Level of detail & delegation

- ***Lower level rules are derived from and must comply with higher levels***
- ***A problem at higher level cannot be corrected by a rule at lower level***

TOTAL

TAKE - AWAYS

- LOW ENTROPY is THE fundamental scientific criterion for circularity of materials
  - WASTE = high ENTROPY
  - Design for Recycling = Low Entropy Design

- Innovation towards circular plastics = perfectly feasile BUT it needs a *preliminary* focus on circularity, or it will spontaneously lead to more linearity

- The involvement and cooperation of all stakeholders is essential for circularity


Thank You !